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## Article

# Measuring the Degree of Integration in the Dairy Products Market in Malawi

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**Abstract:** Using monthly data for the period 2006–2011, this study analyzed the degree of spatial market integration in Malawi focusing on two dairy products (liquid milk and powdered milk) sold in the four major towns of the country. The analysis of spatial market integration is important to assess whether to re-establish a dairy processing facility in the northern part of the country. The empirical analysis comprised of the following steps: (1) Integration between prices from different regions were tested using Johansen's cointegration procedure, with the results indicating that, in the long run, prices in some areas move in a similar direction. (2) Two spatial equilibrium models were estimated using a three-regime bivariate threshold vector autoregressive model (TVAR) and a three-regime threshold vector error correction model (TVECM). The results showed that transaction costs were not a cause for concern between the areas thus northern Malawi does not need to re-establish a dairy processing facility as surplus areas (mainly Southern Malawi) can supply the region.

**Keywords:** dairy products; Malawi; spatial price transmission; TVAR; TVECM

## 1. Introduction

The market share of milk processed within Malawi for 2009 were estimated to be attributed to four dairies: Dairibord (70 per cent market share), Suncrest (15 per cent market share), Lilongwe Dairy (10 per cent market share) and Northern Dairies (5 per cent market share) (Revoredo-Giha et al. 2013) and (CYE Consult 2009). Northern Dairies, had a relatively low market share and ceased to operate in 2012 due to cash flow problems and equipment failures (Revoredo-Giha et al. 2013) and CYE Consult (2009). This dairy shutdown raised the question of whether prices of dairy products would increase in this region relative to other parts of the country.

Despite the closure of Northern Dairies, a mini-processing plant opened in 2011 by the Mpoto Dairy Farmers Association (MDFA). Although this processor faces cash flow problems, it continues to collect milk and is currently the only processor available in Northern Malawi, but with a scale of operation that is very limited and with hopes of expanding its capacity to 1000 L per day in the future (USAID and Malawi Dairy Development Alliance 2012). In 2016, it was reported that the machine which processed up to 1000 L was broken and it was unlikely that it would be fixed (The Nation Online 2016). There were concern that this created a situation in which there was no milk processor in the north of Malawi.

The situation facing Northern Malawi raises the question of whether the Government of Malawi and donors should continue promoting dairy processing in the north of the country as the region is characterized by a relatively more diversified production structure (Revoredo-Giha 2012).

This paper aims to understand whether prices for the different dairy products are integrated throughout Malawi's major towns, i.e., whether they move together and the law of one price being satisfied. If prices are found to be integrated, then this would provide evidence to suggest that Northern Malawi should not re-establish a dairy since this implies that trade operates efficiently between the surplus areas of Malawi and the deficit area of the north. Also an understanding of the transaction costs associated with the trade of dairy products to the north is sought. This would help to provide evidence of whether a dairy should be re-established on the basis of large transaction costs. This approach has not yet been applied within the dairy context of Malawi and is considered to be novel within this regard.

The structure of the paper is organized as follows: it starts with a background, followed by a description of the data used in the analysis, which is then followed by the methodology. The final section presents and discusses the results, and that is followed by the conclusions.

## 2. Background

This paper is focused on understanding whether dairy product prices in Northern Malawi move in a similar direction to the rest of the country. However, it is important to understand some of the background surrounding the dairy sector in Malawi as improved milk availability through increased production is an aim of the Malawian government (Revoredo-Giha et al. 2013). The situation regarding dairy production in Northern Malawi would suggest that it is not best suited to this region relative to the other regions in the country. This section will cover the three parts that are important to understanding the whole dairy supply chain for Malawi: the dairy market structure, dairy farms and milk consumption in Malawi.

Tebug et al. (2012) indicated how low prices offered to northern farmers are ranked the fourth biggest constraint<sup>1</sup> for the production of milk in the area. Therefore, if milk prices are not cointegrated between the north and rest of the country, then this could imply that the law of one price does not apply and there are market distortions.

All three milk processors operate in the south and central areas of Malawi. Dairibord marketed the majority of dairy products (approximately 70%) (Revoredo-Giha et al. 2013). The main operations of Dairibord are located in Blantyre, which is in the south of the country (Dairibord Holdings Limited 2014). The remaining dairies are Suncrest Creameries, located in Blantyre, and Lilongwe Dairies, located in Lilongwe (central Malawi) (Revoredo-Giha et al. 2013). Northern Dairies Industries, which ceased production in 2012, was located in the northern town of Mzuzu (Revoredo-Giha et al. 2013).

Despite the failure of Northern Dairies Industries, it seems that the north of the country has greater farm diversity (small holder farms) in terms of livestock ownership and the proportion of land used for market crops relative to the rural south (Jones et al. 2014). It would appear that the majority of the breeds of cows used in the north are "exotic" (i.e., foreign) relative to the central areas, which tend to use cross breeds (Tebug et al. 2012). According to (Tebug et al. 2012), the major constraint for northern farmers is the "unreliable supply of improved animal genetics", which arose through problems of importing semen for artificial insemination. This highlights how the breed of the cow is important for milk production in Malawi and provides evidence as to why central and southern regions have dairies in operation. However, the organization of Malawian farmers in milk bulking groups (MBGs) is also an important consideration to the success of the dairy.

There is also evidence to suggest that a major constraint to dairy farming in the north is due to the higher transport costs associated with the long distance between the farm and the milk bulking group (MBG) (Tebug et al. 2012). This may provide one of the reasons why Northern Dairies Industries

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<sup>1</sup> The six constraints were ranked: Unreliable supply of improved animal genetics, Poor animal health, Feed shortage, Low prices for milk, Poor farm management and Poor farmer group management.

ceased production. Transport costs have been mentioned by [Mtumbuka et al. \(2014\)](#) as affecting overall transaction costs in Malawi.

[Tebug et al. \(2012\)](#) suggested that involving dairy processors from the rest of the country could improve the marketing of milk products for these northern farmers. However, with the recent closure of Northern Dairies, MBGs may have been scaled back to reflect less industry demand for raw milk. Statistics from 2015 suggest that the eight northern MBGs contributed approximately 2% to the country's overall recorded milk production ([The Nation Online 2016](#)).

It should be noted that farmers do not necessarily sell all their milk to MBGs, as some will be consumed by their family and or sold in rural areas. According to the Malawian [Milk and Milk Products Act \(1990\)](#), all milk products sold in urban areas must be sterilized. However, this rule does not apply to rural areas hence the ability for farmers to legally sell their milk in these areas without the need for MBGs and eventual dairies to sterilize the product.

With regards to consumption, [Jones et al. \(2014\)](#) found (from their survey) that the highest level of consumption of dairy products (out of all the rural regions) occurred in the north. Unfortunately, similar information for the northern town of Mzuzu could not be sourced. This suggests that demand for dairy products exists in the rural north and is also likely to be true for the urban north.

From a policy perspective, it is important to assess whether a dairy in the north of Malawi should be re-established using empirical evidence. A further issue for policymakers is how markets which are not operating "efficiently" can make desired aims of macroeconomic policy implementation more difficult to achieve ([Barrett 2005](#)).

### 3. Data

The data for this study were provided by Malawi's National Statistical Office in the form of price indices ([National Statistical Office of Malawi 2013](#)). Only the urban areas (Lilongwe, Blantyre, Zomba and Mzuzu) are of interest, given the information that milk must be pasteurized to be sold in these areas, thus the price indices are likely to be more representative of urban areas. The following prices of products were included: fresh milk and powdered milk. Data on other dairy related products were available, such as cheese and margarine. However, these products are not the focus of this paper. The data covered the years January 2006 until April 2011. Unfortunately, more recent data were not available that could have accounted for the post closure of the dairy in Northern Malawi. The data for fresh milk are produced by the MDI dairy, which was responsible for collecting 2.4% of the milk bulking group's raw milk in 2011 ([Leat et al. 2013](#)). Therefore, this milk product may not be considered representative of Malawian fresh milk. However, as these were the only fresh milk price data covered by Malawi's National Statistical Office, it must be assumed that they were considered representative of other fresh milk price indices. As the powdered milk has a longer shelf life, it is assumed that this product is more representative of all the dairy products in this study (given the lack of refrigeration facilities).

Prices can grow exponentially over time. Therefore, natural logarithms were used for both series ([Verbeek 2008](#), p. 297). Whilst the prices are indices, this is acceptable for the threshold model used by [Lo and Zivot \(2001\)](#).

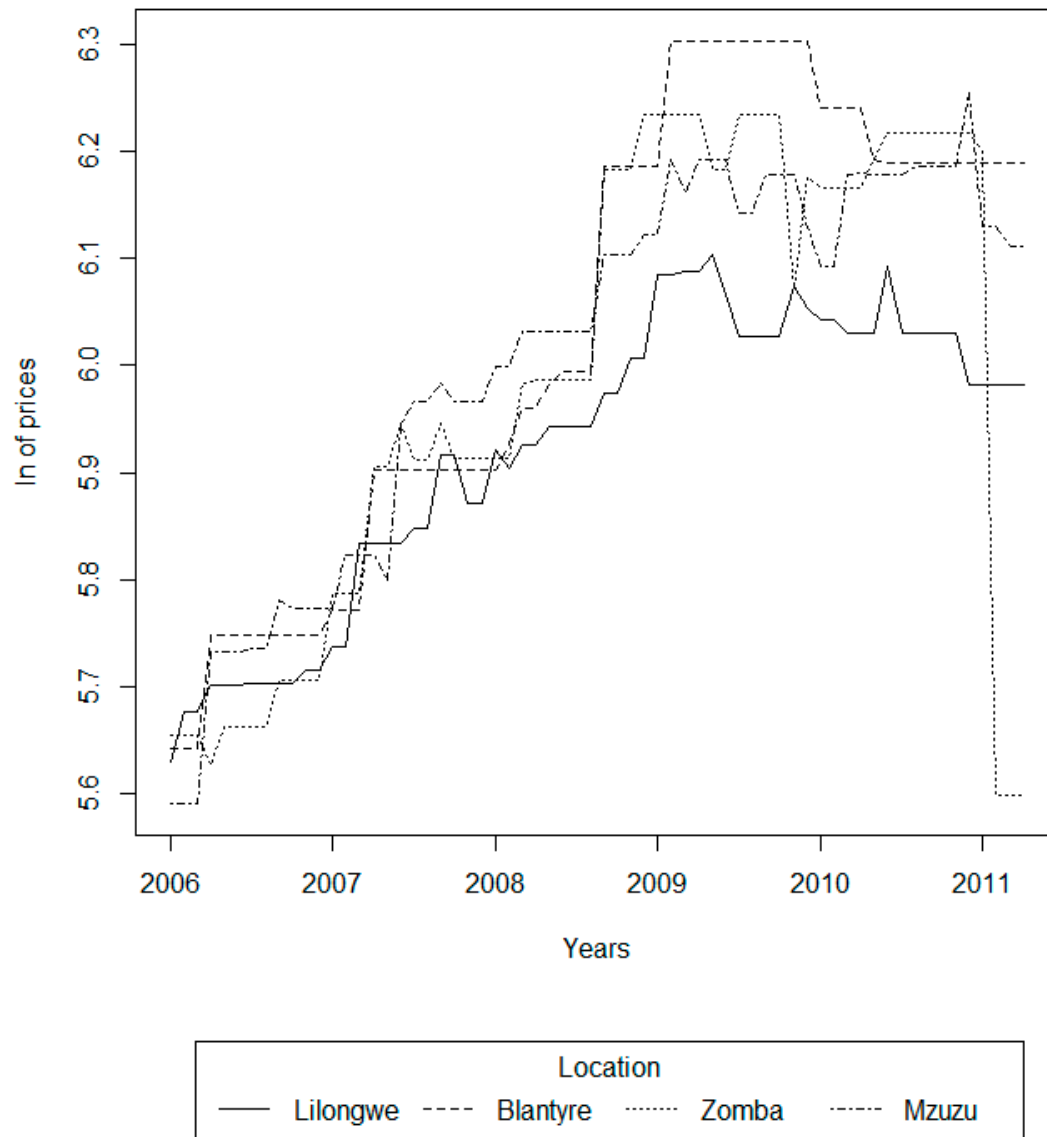
Google maps provided data for the urban pairings in the form of Table 1 ([Google 2014](#)). Table 1 shows that the pairing of Mzuzu to Blantyre are furthest and takes the longest to complete by driving.

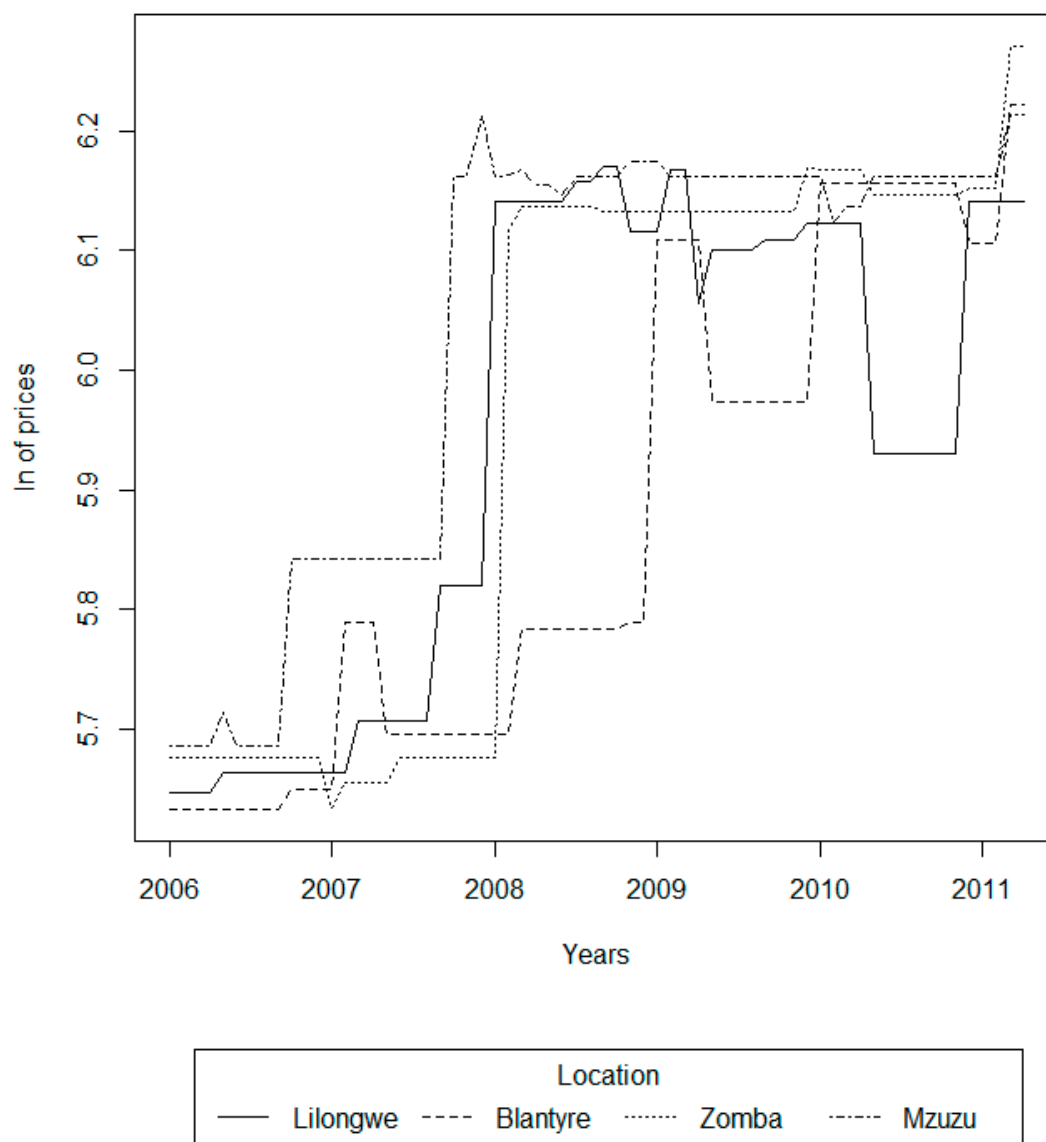
Figures 1 and 2 show that, in general, product prices appear to be moving in the same direction with regards to their respective locations. Figure 1 does show a slight exception for the town of Zomba, where there was a relatively large reduction in the price of fresh milk in 2011. Figure 2 also shows a similar price reduction for the beginning of 2011 with regards to powdered milk sold in Mzuzu. [Google \(2014\)](#) provided the approximate distance time through their map service. This paper is not suggesting that the distance times are fully accurate but they offer an indication of the time required to transport dairy products. The authors of this paper did not visit Mzuzu while in Malawi, hence these times cannot be verified.

**Table 1.** Distances between main towns.

Location Pairs	Distance by Road (km)	Google Estimated Driving Time
Mzuzu to Lilongwe	358	4 h, 36 min
Blantyre	606	7 h, 47 min
Zomba	578	7 h, 30 min

Source: Google Maps road distance search (2 October 2014).

**Figure 1.** Fresh milk prices. Source: National Statistical Office of Malawi.



**Figure 2.** Powdered milk—Anchor prices. Source: National Statistical Office of Malawi.

## 4. Methods

### 4.1. Cointegration Test

The Johansen co-integration tests used in [Goodwin and Piggott \(2001\)](#) found that the market pairs of the agricultural commodities (corn and soybeans) studied were mostly found to be cointegrated. The authors highlighted that the strong likelihood of cointegration indicated that there was likely a long-run relationship between the markets of interest in the spatial price transmission study ([Goodwin and Piggott 2001](#)). [Goodwin and Piggott \(2001\)](#) used the augmented Dickey–Fuller test for investigating the presence of unit roots in the time series data.

The conclusion of unit roots being present can be supported using the augmented Dickey–Fuller (ADF) test of different forms, such as including a time trend in addition to understanding the number of lags present. [Abdulai \(2000\)](#) and the aforementioned [Goodwin and Piggott \(2001\)](#) used an ADF test although other unit roots tests such as the Philips–Perron unit root can be used. In order to determine the number of lags present in the ADF test, the Akaike’s information criterion (AIC) can be used.

This study opted for the Johansen procedure (for checking cointegration of the time series of interest) as it is quite likely that when using multiple time series, there is more than one cointegrating

relationship which exists (Verbeek 2008, p. 358). Other studies have also used the Johansen procedure to test for cointegration (Abdulai 2000; Goodwin and Piggott 2001). Essentially, the Johansen procedure is comprised of a vector autoregressive model that is calculated by the maximum likelihood method which allows for the number of cointegrating vectors (relationships) to be estimated (Verbeek 2008). Therefore, the Johansen procedure will be applied to all price series and applied for the pairs.

#### 4.2. Threshold Vector Autoregressive Model (TVAR)

Threshold effects are when a large shock, such as a transaction cost increase, creates a different price response than a smaller shock and causes a localized price difference which exceeds the neutral band (i.e., the range for which prices are not related to one another) (Goodwin and Piggott 2001). If the long-run price relationships are cointegrated, then an understanding can be sought on the presence of threshold effects. This is because the long-run relationship allows for an understanding of whether the law of one price applies to the good of interest and threshold effects allows for an understanding of the short-term deviations (Lo and Zivot 2001). Goodwin and Piggott (2001) studied threshold effects which could be attributed to transaction costs using a threshold autoregression and threshold error correction models. Their study found interesting results, such as that the difference in price between two locations in North Carolina would have to differ by 3.8% before exceeding the “neutral band”, thus invoking price adjustments (Goodwin and Piggott 2001).

A more recent study which looked at transaction costs between different markets in Tanzania using a TAR model found that the closer the two markets (Dodoma and Iringa) are, the lower the transaction costs (Van Campenhout 2007). The results from the study’s TAR and TAR with a trend both indicate that the linkages between Dodoma and Iringa have the lowest threshold values of 2.15% and 2.63%, respectively (Van Campenhout 2007).

The three-regime bivariate (known as threshold multivariate) VAR model (TVAR) has been adapted from Lo and Zivot (2001)’s study and estimated using R package “tsDyn” (Di Narzo et al. 2014). The general three-regime TVAR is represented by Equation (1).

$$p_{it} = \alpha^{(j)} + \phi_1^{(j)} p_{t-1} + \phi_2^{(j)} p_{t-2} + \dots + \phi_k^{(j)} p_{t-k} + \epsilon_t^{(j)}, \text{ if } c^{(j-1)} \leq z_{(t-d)} \leq c^{(j)} \quad (1)$$

$p_{it}$  represents the log price and location of the dairy product.  $k$  is the lag length and  $z_t$  represents the threshold variable. The delay parameter,  $d$ , has been highlighted by Goodwin and Piggott (2001) and is equal to one in most applications.  $c$  represents threshold values and for the purposes of Equation (1) and this study, only two values are estimated. Finally,  $j$  represents the threshold level which becomes apparent in Equation (2).

A potential problem with using a delay parameter of one month ( $d = 1$ ) is that deliveries of fresh milk take place at a greater frequency than one month. However, with regards to MDI dairy produce (fresh milk), a very low share of milk exists relative to other Malawian dairies. However, for powdered milk, deliveries could potentially take place once a month as it can be stored for a longer period of time.

The threshold values are subject to the three regimes (Equation (2)), whereby the model allows the share of observations in each regime to be estimated. Regime two is where observations lie within the two threshold values, whilst the other regimes provide for an indication of where observations deviate from the thresholds.

$$\begin{aligned} \text{Regime 1 : } & -\infty < v_{t-d} \leq c^{(2)} \\ \text{Regime 2 : } & c^{(2)} < v_{t-d} \leq c^{(1)} \\ \text{Regime 3 : } & c^{(1)} < v_{t-d} < \infty \end{aligned} \quad (2)$$

Threshold two in the TVAR model has similarities to the “neutral band” of the threshold error correction model (TVECM) where observations which deviate from this regime would deviate from the equilibrium and thus be contained in other bands (Goodwin and Piggott 2001). However, the error correction model is not identical to the TVAR for reasons which will be discussed.



While the cointegration tests allow inference of long-term price converges, the short term is where the TVAR model allows for an understanding of when deviations from the long-term steady state appear (Balke and Fomby 1997). The TVAR in Equation (1) has similarities with the threshold error correction model (TVECM) of Equation (3). However, the TVAR derives from autoregressive models (Lo and Zivot 2001). An alternative error correction model is the BAND TVECM, whereby, instead of the deviation returning to an “equilibrium point”, it returns to a specified band (Balke and Fomby 1997). However, there is the additional requirement placed on the cointegrating residuals, such as remaining stable in outer bands and the middle regime not being cointegrated (Lo and Zivot 2001). Goodwin and Piggott (2001) suggest that the TVAR condition of being symmetric can be restrictive and may imply that more observations are in the neutral zone relative to the TVECM. This provides justification for this study to run both a TVAR and TVECM.

While Goodwin and Piggott (2001)’s paper is primarily concerned with both finding the threshold effects (in form of half-life) and then performing a grid search in order to discover alternative regimes, this study is only interested in discovering the thresholds to understand whether the distance between locations increases the two estimated threshold values, thus the overall transaction costs. The TVAR model can use price indices as demonstrated by Lo and Zivot (2001) with their application of using a monthly consumer price index in order to examine different household products, such as meat prices between major US cities.

#### 4.3. Threshold Vector Error Correction Model (TVECM)

The threshold vector error correction model (TVECM) is represented by three regimes. With regimes one and three and the observations would likely result in price transmission through “violation of spatial equilibrium” (Greb et al. 2013). Equation (3) shows the three regimes of the TVECM and appears in Park et al. (2007). The three regimes are represented by  $Z_{t-d}$  which is the threshold variable. The error terms of the three regimes are assumed to equal one another. A lag of one was used based on the results of the ADF test from Table 2.

$$\Delta P_t = \begin{cases} \theta_1 X_{t-1} + e_t^{(1)}, & \text{if } -\infty = C^{(0)} \leq Z_{t-d} < C^{(1)} \\ \theta_2 X_{t-1} + e_t^{(2)}, & \text{if } C^{(1)} \leq Z_{t-d} \leq C^{(2)} \text{ and} \\ \theta_3 X_{t-1} + e_t^{(3)}, & \text{if } C^{(2)} \leq Z_{t-d} \leq C^{(3)} = \infty \end{cases} \quad (3)$$

**Table 2.** Augmented Dickey–Fuller test results.

		Level Series Augmented–Dickey Fuller (ADF) Test Statistic					First Differences ADF Unit	
Product	Location	Constant and time trend	tau value	No constant or time trend	AIC Lag 1/	Type favored	root test	
			Constant				Unit root test statistic	Order of integration
Fresh milk	Lilongwe	−0.51	−1.99	1.61	1	No Trend or Drift	−5.43 2/	I(1)
	Blantyre	−0.85	−1.86	1.83	1	No Trend or Drift	−5.35 2/	I(1)
	Zomba	0.23	−1.45	−0.13	1	No Trend or Drift	−5.46 2/	I(1)
	Mzuzu	−1.49	−2.75	1.85	1	No Trend or Drift	−6.15 2/	I(1)
Powdered milk Anchor	Lilongwe	−1.60	−1.60	−1.41	1	No Trend or Drift	−5.66 2/	I(1)
	Blantyre	−3.34	−0.76	1.28	1	No Trend or Drift	−5.28 2/	I(1)
	Zomba	−2.03	−0.94	1.22	1	No Trend or Drift	−5.25 2/	I(1)
	Mzuzu	−1.66	−1.72	1.43	1	No Trend or Drift	−4.85 2/	I(1)

Notes: 1/ Akaike’s Information Criteria (AIC) used for selecting lag length; 2/ Denotes that  $H_0$  I(2) is rejected in favor of  $H_1$  I(1) in terms of order of integration (using tau statistic). The ADF test requires use of other test statistics apart from tau. Due to space constraints, the other test statistics (such as phi) have not been included. Source: Own elaboration based on data obtained from the National Statistical Office of Malawi.

This paper acknowledges the problem of TVECM possibly being biased due to the selection of the trimming parameter, whereby a minimum number of observations are set to be contained in each regime (Greb et al. 2013). However, this paper still used the TVECM as it allows somewhat of a comparison with Goodwin and Piggott (2001)’s paper and still allows for an understanding of thresholds. Greb et al. (2013) discuss previous literature where the trimming parameter is set at



between 15 and 20% of observations (observation made to be in each regime) which are described as potentially too high for small samples in well-integrated markets. This study has set a trimming parameter value of 5% for most pairings. The only pairing which did not have this value was Mzuzu to Lilongwe; a value of 1% for powder milk was set as the model returned errors at 5%.

The TVECM is estimated using R package “tsDyn” and the linear cointegrating parameter is estimated in the package (Di Narzo et al. 2014).

## 5. Results and Discussions

### 5.1. Cointegration Test

The ADF test would imply that each price series shown in Table 2 contains unit roots which are a condition for cointegration. The ADF test requires many steps in order to conclude that the data series is non-stationary. The AIC suggests the selection of one lag for each series. All the data series were found likely to be integrated to the order of one I(1). To ascertain this, the last test required testing a null hypothesis of the I(2) price series against the alternative hypothesis of a I(1) price series. The tau statistic concluded that the null hypothesis was rejected and the alternative hypothesis was accepted.

As the price series in the analysis were found to contain unit roots, the aim of this paper was, therefore, to test whether the price series are cointegrated for two dairy products (fresh milk and powdered milk) based on their geographical location. The urban areas were Lilongwe, Blantyre, Zomba and Mzuzu, with Mzuzu being the northern city of interest. The Johansen cointegration procedure was used as this allows some inference on the number of cointegrating relationships within the data.

The Johansen cointegration test results (Table 3) found it likely that four cointegrating vectors existed at 1% statistical significance level. This does provide evidence to suggest that there is a likely cointegrating relationship for the products with regards to their respective four markets (i.e., Lilongwe, Blantyre, Zomba and Mzuzu). This result helps to support the idea of the law of one price being applicable, at least in the long run to these products in the different locations. However, it should be noted that the informal sectors of dairy marketing cannot be covered in this paper owing to data constraints. The estimation of the cointegration of fresh milk raised a warning message and the test could not estimate the test statistic for the first null hypothesis, since there were zero vectors of cointegration. However, it seems very likely given the other null hypothesis results that the test statistic should allow the rejection of the null hypothesis.

Table 3. Cointegration tests.

Johansen-Procedure: Maximal Eigenvalue Statistic (Lambda Max)								
Null Hypothesis	test	Fresh milk			Powdered milk (anchor)			
		Without linear trend and constant			Without linear trend and constant			
		10pct	5pct	1pct	test	10pct	5pct	1pct
$r \leq 3$	14.25	7.52	9.24	12.97	25.04	7.52	9.24	12.97
$r \leq 2$	29.83	13.75	15.67	20.2	121.35	13.75	15.67	20.2
$r \leq 1$	322.89	19.77	22	26.81	432.41	19.77	22	26.81
$r = 0$	NaN 1/	25.56	28.14	33.24	1164.1	25.56	28.14	33.24

Notes: 1/“NaN” is a warning message displayed in “R” though it seems likely that the  $H_0$  test statistic for  $r = 0$  would be rejected at 1% statistical significance level. Source: Own elaboration based on data obtained from the National Statistical Office of Malawi.

Pairwise cointegration tests were run with regards to Mzuzu and are shown in Tables A1–A3 within Appendix A. With regards to fresh milk, results suggest that cointegration exists between Mzuzu and Blantyre but not for the other pairings. This result does suggest that pairings of either Lilongwe or Zomba to Mzuzu do not experience the law of one price in the long run, hence the focus should be on the Mzuzu to Blantyre pairing. With regards to powdered milk, it is likely that all pairings have a cointegrating vector.

The cointegration results would imply that, in the long run, the theory of the law of one price holds (at least for the Mzuzu to Blantyre pairing), which suggests that retailers price dairy products at a similar level. However, the deviations from this level in the short term are where the threshold models are of particular interest hence the focus of this paper on spatial market integration.

## 5.2. Threshold Vector Autoregressive and Vector Error Correction Models

In order to account for transaction costs, both a threshold vector autoregressive model (TVAR) and threshold vector error correction model (TVECM) are used.

The urban threshold pairs concern how the flow of dairy products go to the northern town of Mzuzu, hence all pairings start with Mzuzu. In [Goodwin and Piggott \(2001\)](#)'s paper the focus was on the main market trading town of Williamston for corn hence this town was the last pairing as corn was being delivered there. The larger thresholds equate to larger transaction costs ([Goodwin and Piggott 2001](#)). Since Mzuzu is unlikely to be an exporter of dairy products it would not make sense to have it as the last pairing. One problem with the data range used is that the most recent period was April 2011, which covers a time during which Northern Dairies Industries was still in operation and this may have distorted the results. However, it seems unlikely that Northern Dairies Industries was an efficient processor since it closed in 2012. Tables 4 and 5 show the TVAR and TVECM modelling results.

**Table 4.** Threshold vector autoregressive model (TVAR) threshold values.

Products	Market Pairs	Lower Threshold Value	Higher Threshold Value	AIC	BIC	Observations In Each Regime (%)		
						1	2	3
Fresh milk	Mzuzu–Lilongwe	5.80	6.18	−878.34	−810.33	21	64.5	14.5
	Mzuzu–Blantyre	5.80	6.14	−828.24	−760.18	21	50	29
	Mzuzu–Zomba	6.11	6.14	−766.45	−698.40	59.7	11.3	29
Powdered milk (anchor)	Mzuzu–Lilongwe	6.14	6.16	−785.77	−717.70	37.1	51.6	11.3
	Mzuzu–Blantyre	5.84	6.16	−727.26	−659.19	32.3	56.5	11.3
	Mzuzu–Zomba	5.84	6.16	−724.94	−656.88	32.3	56.5	11.3

Notes: 1/Akaike's Information Criteria (AIC); 2/Bayesian Information Criteria (BIC). Source: Own elaboration based on data obtained from the National Statistical Office of Malawi.

**Table 5.** Threshold vector error correction model results.

Products	Market Pairs	Lower Threshold Value	Higher Threshold Value	AIC	BIC	Observations In Each Regime (%)		
						1	2	3
Fresh milk	Mzuzu–Lilongwe	−0.121	−0.002	−860.012	−804.707	8.10	80.60	11.30
	Mzuzu–Blantyre	−0.033	0.015	−813.055	−757.749	64.50	17.70	17.70
	Mzuzu–Zomba	−0.007	0.016	−769.027	−713.722	14.50	12.90	72.90
Powdered milk (anchor)	Mzuzu–Lilongwe	−0.019	0.143	−711.503	−631.290	36.10	47.50	16.40
	Mzuzu–Blantyre	−0.006	0.225	−713.822	−658.517	56.5	30.6	12.9
	Mzuzu–Zomba	−0.064	0.098	−737.164	−681.858	74.2	17.7	8.10

Notes: 1/Akaike's Information Criteria (AIC); 2/Bayesian Information Criteria (BIC). Source: Own elaboration based on data obtained from the National Statistical Office of Malawi.

The threshold values of urban fresh milk<sup>2</sup> (Table 4) reveal that the largest gap between threshold values<sup>3</sup> is for the pairing Mzuzu–Lilongwe. However, in terms of where the majority of observations occur, the TVAR and TVECM have similar results. The relatively large thresholds may be a result of transportation costs. With regards to the frequency of observations for the pairing of Mzuzu–Lilongwe, the results suggested that the majority of observations are in the middle regime (i.e., regime 2) which is likely to be a result of the towns being close to one another hence possible market integration. This highlights that the thresholds should be covered alone. The TVECM frequency observation results would suggest that deviations from the equilibrium are not usually large enough to exceed regime 2.

There was a similar result for the pairing of Cofield and Williamston in the study by Goodwin and Piggott (2001) in which the regions were close in terms of distance and had a majority of observations in regime 2.

The Mzuzu–Blantyre pairing is where the two models return somewhat different results. The TVAR indicated that the majority of observations were within regime 2, which is in contrast to the TVECM which indicates regime 1. As the TVAR model is assumed to be symmetric, this may have overestimated the number of observations occurring in the neutral band.

If more data were available, then a more seasonal understanding could be formed as there is low output of fresh milk produced in the dairies of Lilongwe. In 2011, Lilongwe took deliveries of approximately 9.7% of total raw milk (from Malawian milk bulking groups) with the remaining share going to dairies based in the south of the country (including Blantyre) (Revoredo-Giha et al. 2013). This would imply that a relatively small volume of milk is produced in Lilongwe and there may be little available for Mzuzu, thus the transaction costs are higher for Blantyre's fresh milk products (this may support the lack of cointegration vectors in the Mzuzu to Lilongwe pairing). It must be emphasized that MDI (from which the data were sourced) is the smaller dairy in Lilongwe.

With regards to powdered milk, it seems that the lowest thresholds (i.e., transaction costs) found in both the TVAR and TVECM are for Mzuzu to Lilongwe. Also, both models found that the majority of observations were in regime 2, which implies greater market integration (Greb et al. 2013). This result seems credible since the distance is shortest and powdered milk does not require refrigeration vehicles. A recent survey suggests that powdered milk represents the largest share of weekly consumed dairy products and is often imported (Revoredo-Giha and Akaichi 2013).

Due to the dominance of powdered milk in the sampled Malawian diet this is an important result since transaction costs are lowest for this pairing, which suggests that the market is working efficiently. There is also the possibility that as powdered milk can be stored without refrigeration facilities, warehouses in Lilongwe are able to store the products, thus involving lower transaction costs. The distance to the northern towns would support this finding that a greater distance results in greater transaction costs.

The TVECM results for the other pairings differed to the TVAR. While the TVAR reported that the majority observations were in regime 2, the TVECM found that, for both pairings, they were either in regime 1 or 3. A possible explanation for the TVECM result is that should Lilongwe be unable to provide powdered milk, then Blantyre must provide the powdered milk which Greb et al. (2013) explained distorts the spatial equilibrium, thus resulting in price transmission. This could possibly result in a positive price transmission, although more data would be required in order to support this hypothesis. However, both models conveyed a similar finding that the thresholds were larger for the Mzuzu–Blantyre, or the Mzuzu–Zomba pairing, relative to the Mzuzu–Lilongwe pairing.

Whilst some of these findings are similar to Goodwin and Piggott (2001)'s finding that greater distances result in higher transaction costs, there are some differences in terms of the modelling. The TVAR model used in this study offered basic results and would have been improved if a Tsay's test

<sup>2</sup> As fresh milk and powdered milk were found to dominate the dairy consumption shares of Malawians surveyed (Revoredo-Giha and Akaichi 2013).

<sup>3</sup> Threshold value measured by subtracting high and low thresholds.

were available such as in the case of [Goodwin and Piggott 2001](#) although [Abdulai \(2000\)](#)'s study did not use this test. The general finding that transaction costs are higher based on larger distances is supported by the findings of [Mtumbuka et al. \(2014\)](#) who found a similar situation occurring for the Malawian bean market.

## 6. Conclusions

The main findings from this paper indicate that there are similar prices for dairy products across Malawi and that these market pairings with Mzuzu are relatively well-integrated.

Prices of dairy products are likely to be cointegrated at least for the pairing between Mzuzu and Blantyre which suggests that the law of one price applies in the long run. Thus, the market is relatively competitive as retailers are pricing dairy products at a similar level across Malawi. However, this only represents the long run and formal sector. As highlighted in the background section the informal sector is likely to be an important channel for milk supply. However, by virtue of being informal this means that the representative data are difficult to source.

The transaction costs estimated in the form of the threshold values imply that for fresh milk in Mzuzu, the lower transaction costs occurred when paired with Blantyre rather than the closer region of Lilongwe. However, the majority of pairings for the TVECM were in neutral regime 2 which implies that the two markets are relatively well-integrated.

With regards to powdered milk (a product which has lower consumer storage costs and lower transportation costs), the transaction costs are likely to be small for the pairing of Mzuzu to Lilongwe and the majority of observations in the TVECM were in the neutral band. This suggests a relatively well-integrated market pair and requires no intervention in the form of improved infrastructure.

While the data range was not recent enough to include the closure of Northern Dairies Industries, it does suggest that northern Malawi does not require a dairy provided that transaction costs can be reduced for fresh milk.

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## Appendix A

**Table A1.** Cointegration tests between Mzuzu and Lilongwe.

		Johansen-Procedure: Maximal Eigenvalue Statistic (Lambda Max)							
		Fresh Milk				Powdered Milk (Anchor)			
Null Hypothesis	test	Without linear trend and constant				Without linear trend and constant			
		10pct	5pct	1pct		test	10pct	5pct	1pct
$r \leq 1$	3.32	7.52	9.24	12.97		8.36	7.52	9.24	12.97
$r = 0$	10.39	13.75	15.67	20.20		35.31	13.75	15.67	20.20

Notes: Source: Own elaboration based on data obtained from the National Statistical Office of Malawi.

**Table A2.** Cointegration tests between Mzuzu and Blantyre.

		Johansen-Procedure: Maximal Eigenvalue Statistic (Lambda Max)				Fresh Milk				Powdered Milk (Anchor)			
Null Hypothesis		test	Without linear trend and constant			test	Without linear trend and constant			test	Without linear trend and constant		
			10pct	5pct	1pct		10pct	5pct	1pct		10pct	5pct	1pct
$r \leq 1$		10.34	7.52	9.24	12.97	5.06	7.52	9.24	12.97				
$r = 0$		12.56	13.75	15.67	20.20	21.73	13.75	15.67	20.20				

Notes: Source: Own elaboration based on data obtained from the National Statistical Office of Malawi.

**Table A3.** Cointegration tests between Mzuzu and Zomba.

		Johansen-Procedure: Maximal Eigenvalue Statistic (Lambda Max)				Fresh Milk				Powdered Milk (Anchor)			
Null Hypothesis		test	Without linear trend and constant			test	Without linear trend and constant			test	Without linear trend and constant		
			10pct	5pct	1pct		10pct	5pct	1pct		10pct	5pct	1pct
$r \leq 1$		1.65	7.52	9.24	12.97	21.59	7.52	9.24	12.97				
$r = 0$		12.21	13.75	15.67	20.20	72.15	13.75	15.67	20.20				

Notes: Source: Own elaboration based on data obtained from the National Statistical Office of Malawi.

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